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Interim Report on Dispersal of Lobsters, *(Homarus americanus)*, Tagged off Southern Nova Scotia

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INTERIM REPORT ON DISPERSAL OF LOBSTERS, *Homarus americanus*, TAGGED OFF SOUTHERN NOVA SCOTIA

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ABSTRACT

Campbell, A. 1989. Interim report on dispersal of lobsters, Homarus americanus, tagged off southern Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 2022: 29 p.

Of the 9254 American lobsters (Homarus americanus) tagged and released in five inshore and midshore locations off southern Nova Scotia during 1983-87, 1298 (14.0%) were recaptured within 5 yr of release. Mature lobsters (≥ 95 mm carapace length, CL) moved on average significantly greater distances than immature lobsters (<95 mm CL). Most (94%) immature lobsters were recaptured less than 18.5 km (10 M) from the release areas, whereas for mature lobsters this percentage was 59%. Many (22.7%) mature lobsters were recaptured more than 92.6 km (50 M) from the release locations; the farthest distance moved was 539.7 km for a male caught south of Cape Cod 1.4 yr after release. General direction of travel was south with some east and west interchange between inshore and offshore areas such as Crowell Basin, the continental slope of Georges and Browns Banks, the Gulf of Maine and southern Nova Scotia. There was movement of lobsters from east to west and from west to east of the Cape Sable area, the southern tip of Nova Scotia, suggesting there is some mixing between lobster stocks off eastern Nova Scotia and southwestern Nova Scotia. The long distance movement and mixing of mature lobsters suggests that attempts to use tagging information in locating biological boundaries between lobster stocks in the Gulf of Maine, adjoining Continental Shelf, Scotian Shelf and inshore areas of southwestern Nova Scotia and southern end of eastern Nova Scotia may be a difficult task.

Key words: American lobster, movement, tagging, Homarus americanus

RÉSUMÉ

Campbell, A. 1989. Interim report on dispersal of lobsters, Homarus americanus, tagged off southern Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 2022: 29 p.

Parmi 9254 homards américains (Homarus americanus) marqués et relâchés, de 1983 à 1987, en cinq points des zones côtière et semi-hauturière au sud de la Nouvelle-Écosse, 1298 (14,0%) ont été recapturés au cours des cinq années suivant le relâchement. En moyenne, les homards matures (longueur de la carapace ou LC ≥95 mm) ont parcouru des distances beaucoup plus grandes que les homards immatures (LC <95 mm). La plupart (94 %) des homards immatures et 59% des homards matures ont été recapturés à moins de 18,5 km (10 milles marins ou NM) des zones de relâchement. Un bon nombre (22,7%) des homards matures ont été recapturés à plus de 92,6 km (50 NM) des endroits où ils avaient été relâchés; la plus grande distance, à savoir 539,7 km, a été parcourue par un homard mâle capturé au sud du cap Cod 1,4 année après avoir été relâché. Les déplacements s'effectuaient généralement en direction sud, avec certains mouvements d'est en ouest et d'ouest en est entre les zones côtière et hauturière (par exemple bassin Crowell, pente continentale des bancs de Georges et de Brown, golfe du Maine et sud de la Nouvelle-Écosse). Des déplacements d'est en ouest et d'ouest en est ont été notés dans la région du cap de Sable et de la pointe sud de la Nouvelle-Écosse, ce qui indique qu'il y a, dans une certaine mesure, mélange des stocks de homards au large de l'est de la Nouvelle-Écosse et de sud-ouest de la Nouvelle-Écosse. Les grandes distances parcourues et le mélange des stocks de homards matures indiquent qu'il pourrait s'avérer difficile d'utiliser les données de marquage pour localiser les frontières biologiques entre les stocks de homards du golfe du Maine, de la plate-forme continentale adjacente, de la plate-forme Néo-Écossaise et des régions côtières du sud-ouest de la Nouvelle-Écosse et de l'extrémité sud de l'est de la Nouvelle-Écosse.

Mots-clés: homard américain, déplacement, marquage, Homarus americanus

INTRODUCTION

The American lobster (Homarus americanus) is one of the most valuable commercial species in the coastal waters of southern Nova Scotia (Campbell and Mohn 1983; Campbell 1989). Essential to management of this resource is the understanding of the distribution and migration of lobsters in the area. Yet, the geographic discreteness of lobster stocks has been debated for a number of years (e.g. Aiken 1971; Wilder 1974; Stasko 1978; Campbell and Mohn 1983; Pezzack 1987). Recent tagging studies indicated some mixing between lobsters of southwestern Nova Scotia, the Gulf of Maine and adjoining Continental Shelf (Campbell and Stasko 1985). Based on the lack of tag recoveries, Pezzack (1987) suggested that the separation boundary between two lobster stocks of southwestern Nova Scotia and eastern Nova Scotia (Campbell and Mohn 1983) was possibly in the Cape Sable area of the southern tip of Nova Scotia. Although seasonal deep-shallow movements have been shown for lobsters on the continental slopes (Cooper and Uzmann 1971) and in the Bay of Fundy (Campbell and Stasko 1986; Campbell 1986), no similar evidence to date is available for lobsters from the southern Nova Scotia area.

As part of an ongoing series of tagging studies of lobsters off Nova Scotia the main objectives of the present study were to determine (1) if there was lobster movement between the east and west side of the Cape Sable area, the mid and offshore areas and (2) whether lobsters make seasonal deep-shallow movements off southern Nova Scotia. Although the majority of lobsters are caught in inshore areas (<20 km from the coast), an increasing number of inshore fishermen have travelled to the midshore areas (20-92 km from the coast) to catch lobsters (Campbell 1988). Lobsters were tagged in the midshore as well as the inshore areas of southern Nova Scotia (Fig. 1) to take advantage of fishing effort occurring in offshore areas (>92 km from the coast) (Pezzack and Duggan 1983), mid and inshore areas (Sharp and Duggan 1985) in obtaining tag recoveries.

MATERIALS AND METHODS

A total of 9254 lobsters ranging from 20-173 mm CL (carapace length, measured from the base of the eye socket to the posterior margin of the carapace parallel to the mid-dorsal line) was tagged and released at five locations of inshore and midshore areas of southern Nova Scotia from 1983-87 (Table 1; Fig. 1). Trap-caught lobsters were tagged and released within 10 min. of removal from the water and within 0.5 km of the capture site. Each lobster was tagged with a sphyrion anchor tag (Scarratt 1970) inserted with a hypodermic needle into the dorsal musculature between the carapace and abdomen of the lobster, with the coded yellow tubing projecting dorsally. Lobsters at release were categorized as male, female, and as immature (<95 mm CL) and mature (≥95 mm CL) based on the median size at physiological maturity (Campbell 1983) estimated with the ovary examination technique (Aiken and Waddy 1980). Release depth, location, date, CL, sex and tag number of each

lobster were recorded. A reward of up to $5 was paid for tag returns with information on recapture date, location, depth and CL. Data from tag returns up to 31 March 1988 were analyzed in this study.

Of the 1298 recaptured lobsters (14% of total release), data were lacking on 48 recapture locations; these were not used in the analyses. Straight-line distances and direction travelled were calculated from the latitude and longitude of release and recapture locations (Campbell et al. 1983). Lobsters were grouped into four classes of straight-line distances travelled [<18.5 km (<10 M), 18.5-36.9 km (10-19 M), 37.0-92.6 km (20-50 M) and >92.6 km (>50 M)]. Recapture depth and distance travelled were grouped according to season at recapture to investigate the possibility of seasonal movements (1. January-February-March; 2. April-May-June; 3. July-August-September; 4. October-November-December) for immature and mature lobsters. Mean distance moved and recapture depths between areas, size groups and sexes were compared by a one-way ANOVA and Student-Neuman-Keuls test (Kim and Kohout 1975) after transforming distance moved data by $\log_{10}(x+1)$ and depth and time at liberty data by $\log_{10}x$. The geometric means shown are the retransformed means of the logarithmically transformed variables.

Since for each release site and in each size group there were no significant differences ($P>0.05$) between males and females regarding time at liberty, distance travelled and recapture depth, data for both sexes were combined according to each size group and area. The direction of lobster movement was analyzed according to the vector analysis method of Jones (1959), Batschalet (1965) and Saila and Flowers (1968) using a computer program developed by Campbell et al. (1983).

Interpretation of movement data obtained from the recovery of tagged lobsters provided by commercial fishermen should be considered with caution because bias can be introduced by the nonuniform temporal and spatial distribution of fishing effort (see discussions by Fogarty et al. 1980; Bennett and Brown 1983; Campbell and Stasko 1985; Pezzack 1987). Although the open fishing season in the inshore area was from the third tuesday in November until 31 May, most inshore tags were recaptured during periods of high fishing effort during the fall (November and December) and spring (April and May). Tags recaptured offshore were returned year round. The distribution of traps should reflect the location and trapability of lobsters in an area. Fishermen usually concentrate their fishing effort in areas of high productivity where lobster densities are high, but they may also set exploratory traps in areas that are marginally profitable. The closure of Browns Bank to lobster fishing since 1979 (Pezzack and Duggan 1983) reduced the potential recaptures of lobsters moving through this area. Although the rate of tag loss during molting and/or mortality due to poor tag application was unknown, individuals applying tags to lobsters were well trained and experienced so that tag loss was considered minimal. However, Ennis (1986) found tag loss could be between 24-36% for lobsters tagged in Newfoundland. The straight-line distance travelled between release and recapture points can be misleading since some lobsters may undergo seasonal long-distance, deep-shallow migrations, returning close to the original release areas (Campbell 1986; Pezzack and Duggan 1986). The effectiveness of the tag return system is difficult to evaluate and some recaptured lobsters were probably not reported. There is

some doubt whether all fishermen reported tag recaptures since there has been conflict between fishermen groups concerning various management regulations (Campbell 1988). The percentage of tags returned in this study (14%) is comparable with those reported by Campbell and Stasko (1985) but lower than for other areas (Campbell and Stasko 1986; Pezzack 1987). Despite the possible shortcomings of the tag return system, some important information on the movement of lobsters off southern Nova Scotia was obtained.

RESULTS

TIME AT LIBERTY

Of the 9254 lobsters tagged, 14% were recaptured (Table 1). Most lobsters were recaptured within a year of release with fewer returns as time at liberty increased (Fig. 2). The mean time at liberty was significantly longer ($p<0.01$) for lobsters released in area A, probably because they were released 2-3 yr earlier allowing a longer period for recapture than the lobsters released in the other areas (Fig. 2).

DISTANCE MOVED

There were no significant differences ($p>0.05$) in mean distance moved between areas B, C and D for either immature or mature lobsters; consequently the data were combined (Table 2). Most (78.9-99.0%) of the immature lobsters were recaptured <92.6 km from the point of release (Table 2, Fig. 3). By contrast, less than half of mature lobsters were recaptured <18.5 km whereas about a quarter were caught >92.6 km from the release areas A, B, C and D (Table 2). For area E, however, most (86.3%) mature lobsters were caught <18.5 km from the release sites. For each release area, mature lobsters moved a greater mean distance ($p<0.01$) than immature lobsters (Table 2). There were no significant differences ($p>0.05$) in mean distance moved between mature lobsters released in area A and B. In area E, both immature and mature lobsters appeared to move significantly less ($p<0.01$) than those of equivalent size released in the other areas (Table 2, Fig. 3).

There were no consistent seasonal trends in distances moved by either mature or immature lobsters although, with increasing time at liberty, lobsters were generally caught further from the release locations (Fig. 3). Some lobsters were still caught near the release areas even after 4-5 yr at liberty (Fig. 3). The longest straight-line movement recorded in this study was for a 113-mm CL male, released off Wedgeport (Area A) during July 1983 and recaptured 539.7 km away south of Cape Cod after 1.4 yr (Fig. 4); recapture size was not recorded.

DIRECTION OF MOVEMENT

Inspection of the straight-line tracks between release and recapture points of the 130 lobsters that moved >30 km indicated some exchange of lobsters between inshore, midshore and offshore areas off southern Nova Scotia (Fig. 4-8). Lobsters from the inshore areas of southern Nova Scotia (both east and west of Cape Sable) moved to areas such as Crowell Basin, continental slope near Browns Bank, Georges Bank, coastal Maine and south of Cape Cod. Eleven lobsters moved west (Fig. 8) and four moved east (Fig. 4, 6) of the north-south line at Cape Sable. In general, the mean direction of travel was strongest to the south, with a weak west component especially for mature compared to immature lobsters (Table 3). The mean vector angles ($\bar{\theta}$) ranged from 153 to 214 from true north, with the Rayleigh tests indicating a non-uniform distribution for sexes and areas of release (Table 3). Analysis for the possibility of directed seasonal movements, by grouping into seasonal periods, indicated no consistent trends in seasonal direction for either immature or mature lobsters.

DEPTH AT RECAPTURE

Mean depths were significantly greater ($p<0.01$) for mature (geometric mean = 82.2 m) than for immature lobsters (51.6 m) released in areas B, C and D combined, and for mature (28.6 m) compared with immature (17.6 m) lobsters released in area E, all of which were different from the mature lobsters (43.0 m) released in area A. Inspection of depths at recapture grouped by season did not show any consistent patterns. The number of recaptures was small for this detailed analysis and the uneven fall-spring fishing season effort with little effort during the summer made interpretation difficult.

DISCUSSION

This study provides several results indicating that: 1) there was some mixing of tagged lobsters between the areas east and west of Cape Sable, the southern tip of Nova Scotia; 2) mature lobsters moved farther than immature lobsters; and 3) the long-distance movement of some mature lobsters allowed mixing with other lobsters throughout inshore and offshore areas in the Gulf of Maine and the adjoining continental shelf. The latter two findings confirm the results of previous studies by Campbell and Stasko (1985,

1986). There was insufficient evidence to indicate whether or not lobsters conducted seasonal deep-shallow movements in waters off southern Nova Scotia.

The movement of some tagged lobsters between east and west (including southernly dispersal) off Cape Sable suggests that this area is probably not a biological boundary between southwestern Nova Scotia and eastern Nova Scotia lobster stocks as suggested by Pezzack (1987). Examination of other tagging studies (Campbell and Stasko 1985, Fig. 5, 7; Campbell and Stasko 1986, Fig. 7; Pezzack 1987, Fig. 3, 4) indicate some interchange of tagged lobsters in this area (albeit from only a few tag returns). The general southwesterly direction of the long-distance movements of lobsters may be due to the physiographic constraints imposed by the coastline of Nova Scotia (e.g. Fig. 4, 8). However, with the lack of a midshore and offshore fishery off eastern Nova Scotia and the Scotian Shelf (Pezzack 1983, 1984), the extent of lobster movements in this area is difficult to determine. Thus, the use of tagging methods to determine the exact biological boundary, if there is one, between these two stocks is probably, at present, impractical. Other methods such as analysis of landing trends (Campbell and Mohn 1983; Harding et al. 1983), morphometrics (Campbell and Mohn 1982) and examination of isozymes of muscle tissue (Odense and Annand 1978) of lobsters also indicate some overlap between lobster stocks from southwestern and eastern Nova Scotia. Therefore, the use of a boundary between these two lobster stocks near Cape Sable should at present be considered mainly for management purposes of socio-economic convenience, rather than for separation of two biologically distinct lobster populations.

The greater distances moved by mature lobsters compared to immature lobsters found in this study confirms the results of previous studies in the same general area (Campbell and Stasko 1985, 1986). Other studies have also indicated localized movements for most lobsters in the coastal waters of eastern North America (Templeman 1935, 1940; Wilder 1963; Cooper 1970; Stewart 1972; Cooper et al. 1975; Fogarty et al. 1980; Krouse 1980, 1981; Stasko 1980; Campbell 1982; Ennis 1984). Long-distance movements (>100 km) have tended to involve tagged lobsters moving in the Gulf of Maine, Bay of Fundy and the continental shelf (Saila and Flowers 1968; Cooper and Uzmann 1971; Uzmann et al. 1977; Fogarty et al. 1980; Campbell et al. 1984; Pezzack and Duggan 1986). For each area of release the mean distance travelled by tagged lobsters tends to be unique and will depend on a number of factors such as local topography and seasonal environmental conditions and the extent of the tag return system (eg. distribution of fishing effort) (Campbell and Stasko 1986). Although immature lobsters have low dispersal tendencies, the long-distance movements of some mature lobsters and the resultant mixing of lobsters between inshore and offshore areas suggests that there may be a single stock of lobsters in the Gulf of Maine and adjoining continental shelf (see reviews Campbell and Mohn 1983; Pezzack 1987).

Although mature lobsters were found to make deep-shallow seasonal movements in the Bay of Fundy (Campbell 1986; Campbell and Stasko 1986), the present study was unable to determine if this phenomenon occurs for lobsters in the midshore or inshore areas of southwestern Nova Scotia. Anecdotal information, however, suggests these movements do occur, eg. fishermen observations (Aiken 1971) and seasonal diving observations (Campbell, unpubl.

data) suggest some large lobsters are present in shallow waters off McNutt Island during summer but not during winter months.

The present study indicates that some mature lobsters from mid and inshore move to deep offshore areas off southwestern Nova Scotia, supporting, in part, the hypothesis of Stasko (1978) that mature lobsters from inshore could contribute larvae released in offshore areas. Whether these lobsters produce larvae that may eventually return to inshore areas to supplement local larval production and recruitment is a matter of speculation (Campbell and Pezzack 1986). Harding and Trites (1988) however, suggested that lobsters from the Browns Bank contribute larval recruits to the entire southwestern Nova Scotia region and the eastern part of the Gulf of Maine.

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TABLES

Table 1. Summary of release and recapture data for lobsters tagged off southern Nova Scotia during 1983-87. Number of recaptures include individuals with unknown recapture locations. Only arithmetic means shown.

	Release areas				
	A Inshore	B Inshore	C Midshore	D Midshore	E Inshore
			Release data		
General location	Wedgeport	Gannet Rock	Gulley	German Bank	McNutt Is.
	43°38'N	43°39'N	43°35'N	43°22'N	43°37'N
	66°00'W	66°08'W	66°13'W	66°23'W	65°17'W
Dates	22 July-29 Aug	28-29 Sept.	22-26 Sept.	19-22 Sept.	21 July-22 Aug.
	1983	1986	1986	1986	1985-'86-'87
Depth (m) mean	17.3	33.2	61.1	60.4	7.0
(min-max)	(3.7-38.4)	(18.3-36.6)	(49.4-91.4)	(47.5-82.3)	(2.0-12.0)
CL (mm) mean	103.3	82.5	85.1	83.9	71.5
(min-max)	(95-134)	(50-132)	(51-105)	(50-156)	(20-173)
Total no. released	1975	775	775	448	5281
(% mature)	(100.0)	(10.6)	(13.5)	(22.3)	(6.5)
			Recapture data		
No. recaptured	198	87	152	29	832
% recaptured of total releases	10.3	11.2	19.6	6.5	15.8

Table 2. Percentage of total recaptures and mean distance moved of lobsters tagged off southern Nova Scotia. Immature lobsters are 39-94 mm CL and mature lobsters are 95-156 mm CL at release. Geometric means not sharing same letter are significantly different ($p<0.01$) whereas means sharing same letter in same row are not different ($p>0.05$) by the Student-Neuman-Keuls test.

	Release areas				
	A	B,C,D combined		E	
	Mature	Immature	Mature	Immature	Mature
% of total recaptures that moved (km)					
<18.5	47.2	78.9	43.8	99.0	86.3
18.5-36.9	20.4	11.0	10.4	0.3	0
37.0-92.6	4.6	6.0	20.8	0.6	1.0
>92.6	27.8	4.1	25.0	0.1	12.7
Km moved					
Arithmetic mean	60.6	16.7	53.6	3.6	25.8
Geometric mean	27.4[a]	9.2	26.1[a]	1.9	4.0
Maximum	539.7	125.8	177.2	106.0	268.0
Total no. of recaptures					
Distance known	176	218	48	706	102
Distance unknown	22	2	0	19	5

Table 3. Direction statistics for immature (<95 mm CL) and mature (≥95 mm CL) lobsters tagged off southern Nova Scotia. $\bar{\theta}$ = mean vector angle from true north; V and V′ = nonrandom directed movement (km/d) along the north-south and east-west plane, respectively; negative values of V and V′ indicate net southerly and westerly movement, respectively; R and Z = Rayleigh test statistics for randomness of distributed points about a circle; N = number of individuals; * = significant at $p<0.01$ indicating a nonuniform distribution (Batschalet 1965); both sexes are combined.

Direction statistics	Release areas				
	A	B,C,D combined		E	
	Mature	Immature	Mature	Immature	Mature
$\bar{\theta}$	194.6	213.9	202.3	153.3	187.5
V	-0.125	-0.067	-0.236	-0.012	-0.111
V′	-0.033	-0.045	-0.097	0.006	-0.015
R	103.8	75.0	20.3	175.1	26.2
Z	61.6*	25.8*	8.6*	43.5*	6.7*
N	175	218	48	704	102

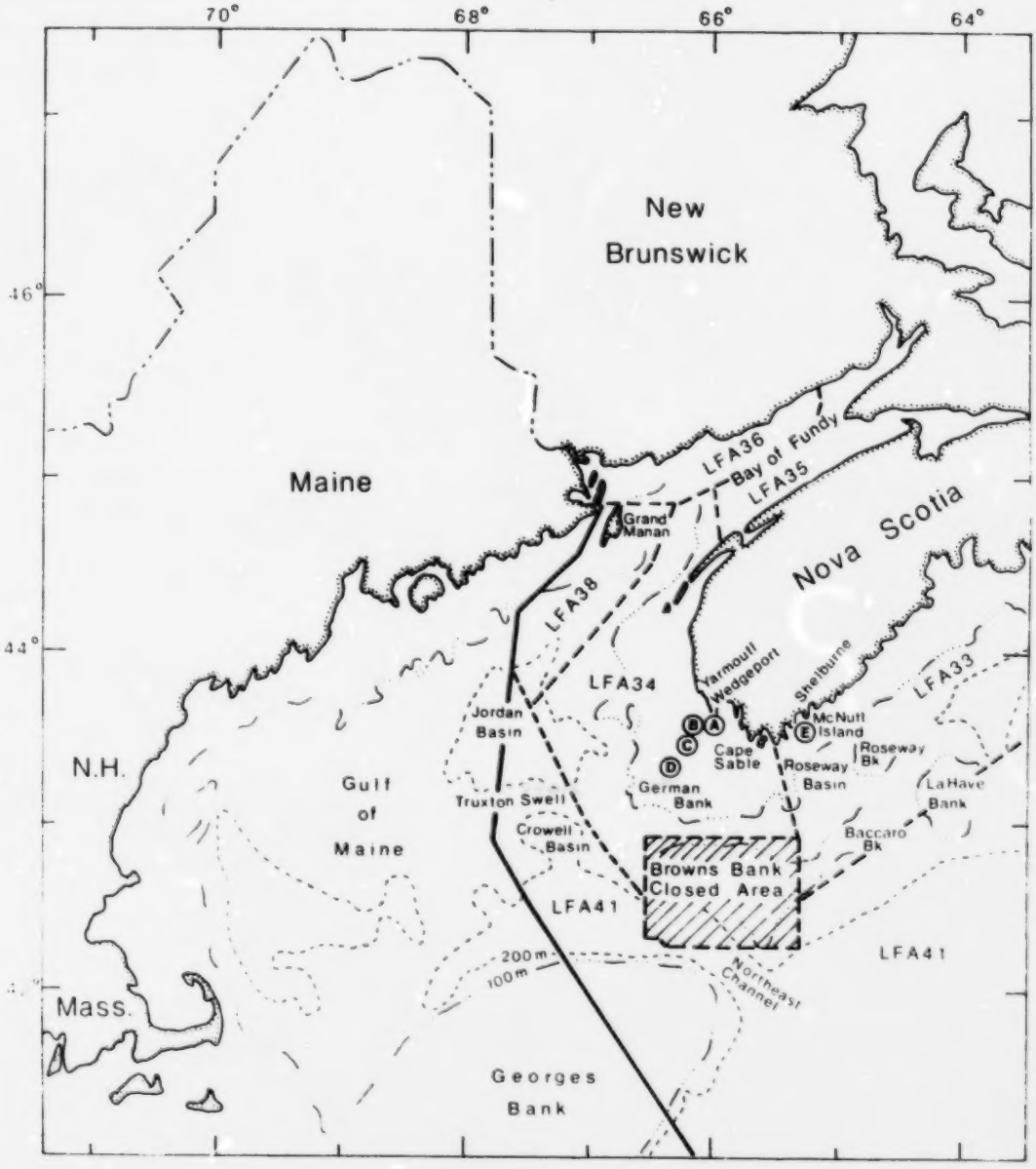

Fig. 1. Tag release sites off southern Nova Scotia. A, Wedgeport; B, Gannet Rock; C, The Gulley; D, German Bank; E, McNutt Island. Offshore boundary and Browns Bank closed area indicated with dashed lines. LFA = lobster fishing areas.

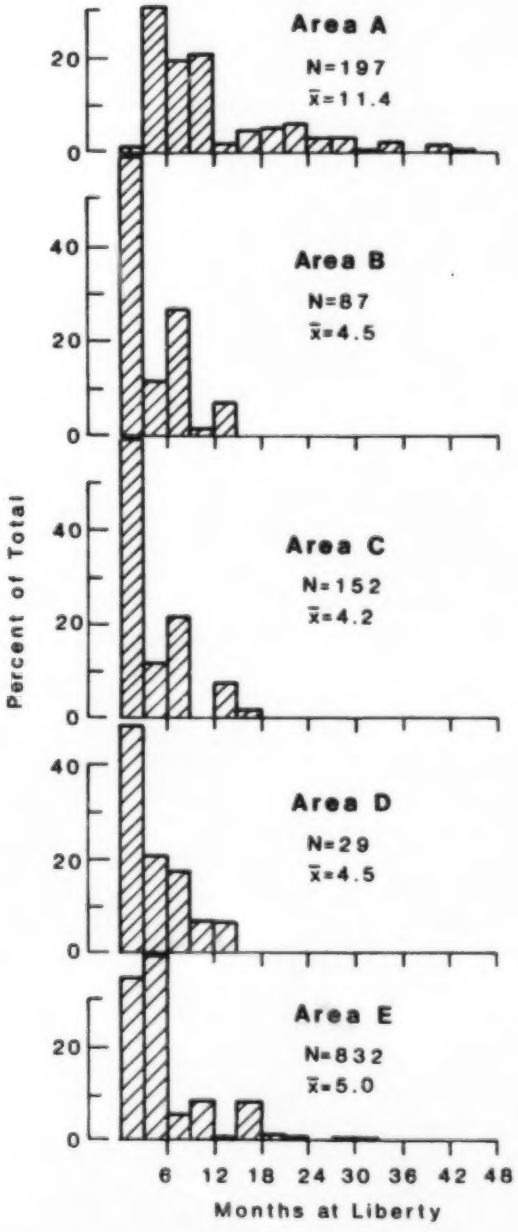

Fig. 2. Percentage of total tag recaptures indicating months at liberty for lobsters released in five areas. See Table 1 and Fig. 1 for release area details. Sexes, immature and mature lobsters combined for each release area. N = number of individuals; X = arithmetic mean.

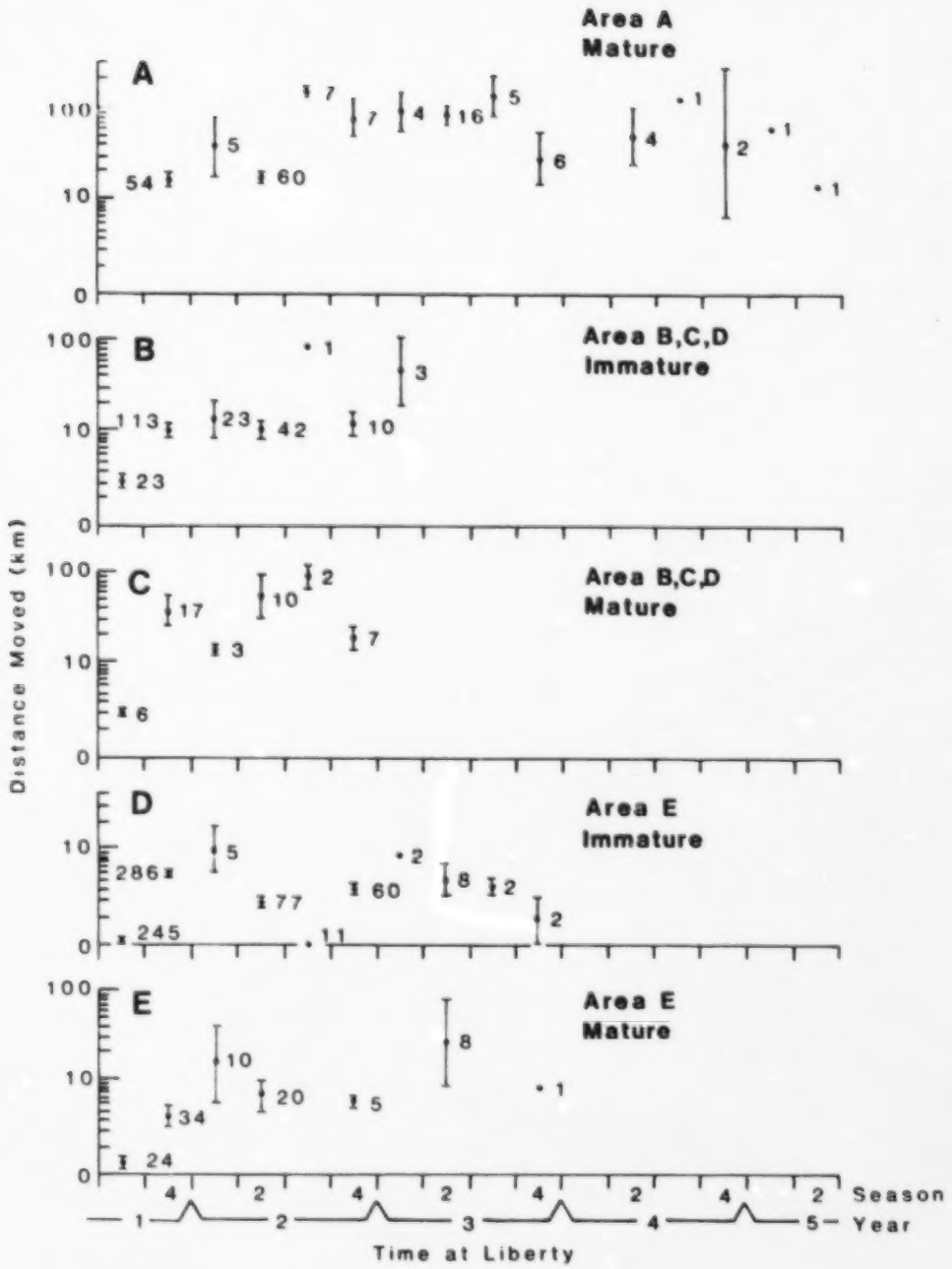

Fig. 3. Mean straight-line distance (km) moved grouped by seasonal (quarterly) period of tagged lobsters released in (a) area A, as mature, (b) areas B,C,D, as immature, (c) areas B,C,D, as mature, (d) area E, as immature, and (e) area E as mature individuals. Dots = geometric means; vertical lines = ± 1 SE; number at each dot = number of individuals recaptured.

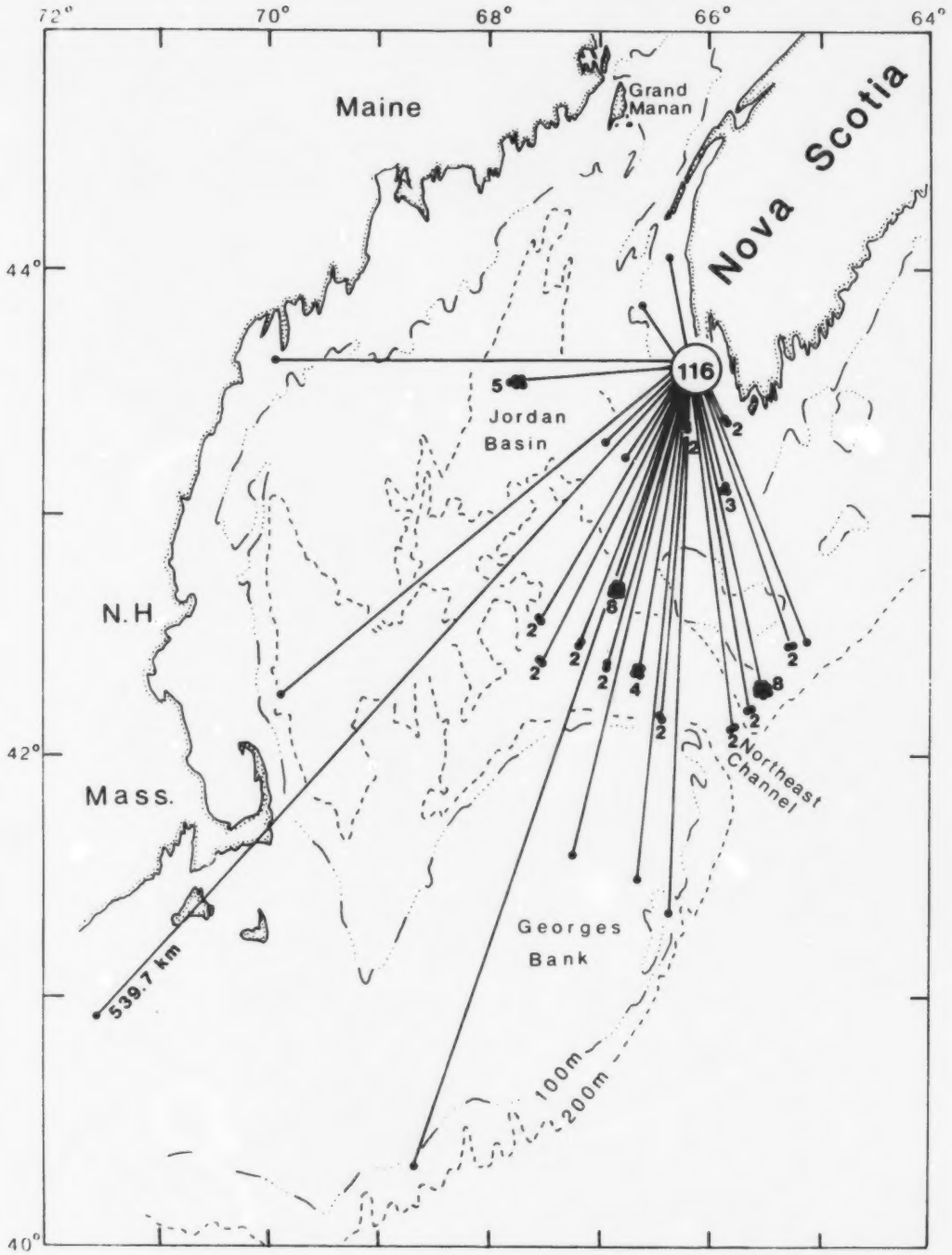

Fig. 4. Recapture points and straight-line distances moved >30 km for tagged lobsters released in area A (near Wedgeport). Each dot represents one recapture, except where a group of dots has a numeral indicating the number of recaptures; 116 lobsters were recaptured within 30 km of the release area A.

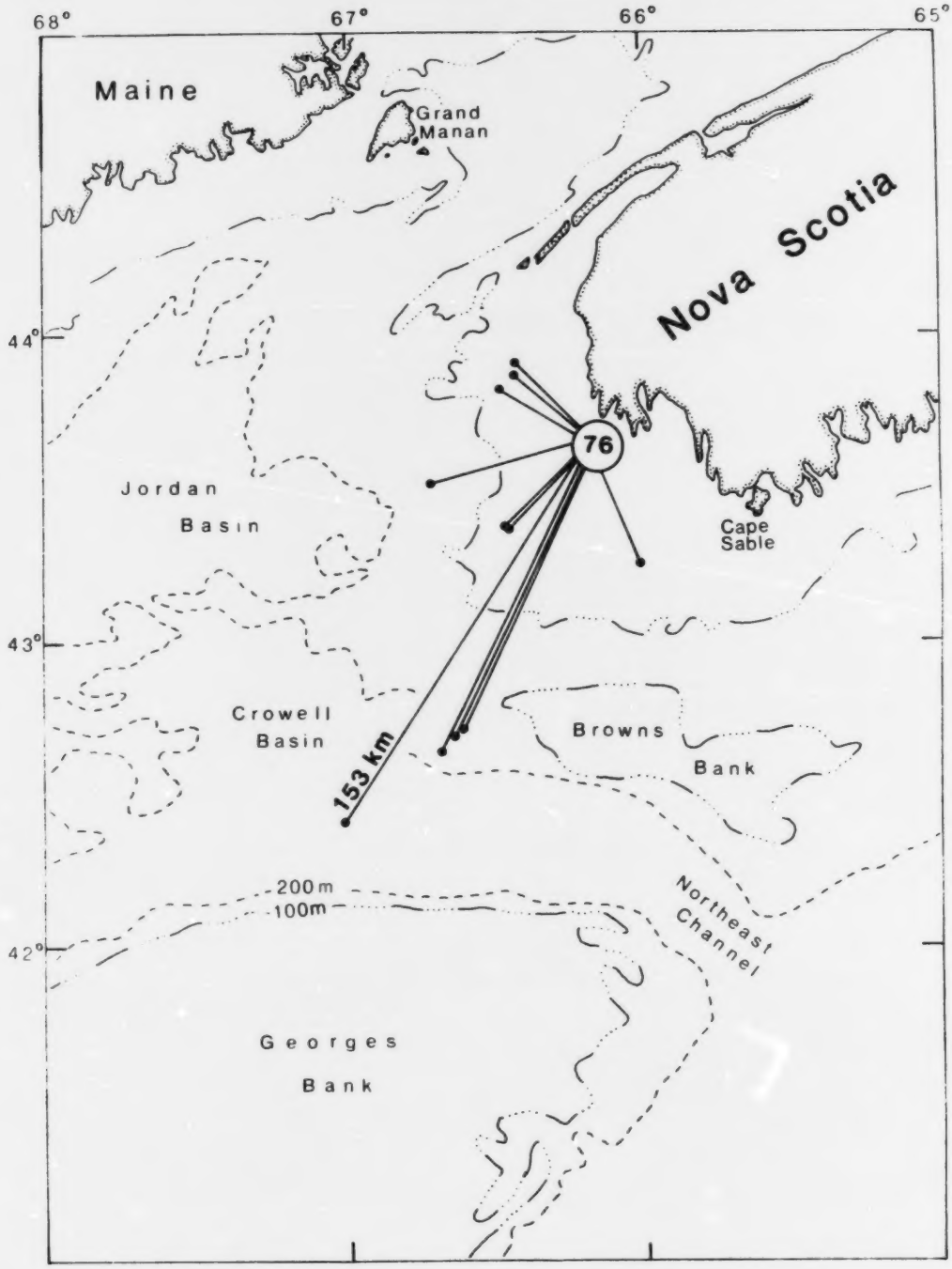

Fig. 5. Recapture points and straight-line distances moved >30 km for tagged lobsters released in area B (near Gannet Rock). Each dot represents one recapture; 76 lobsters were recaptured within 30 km of the release area B.

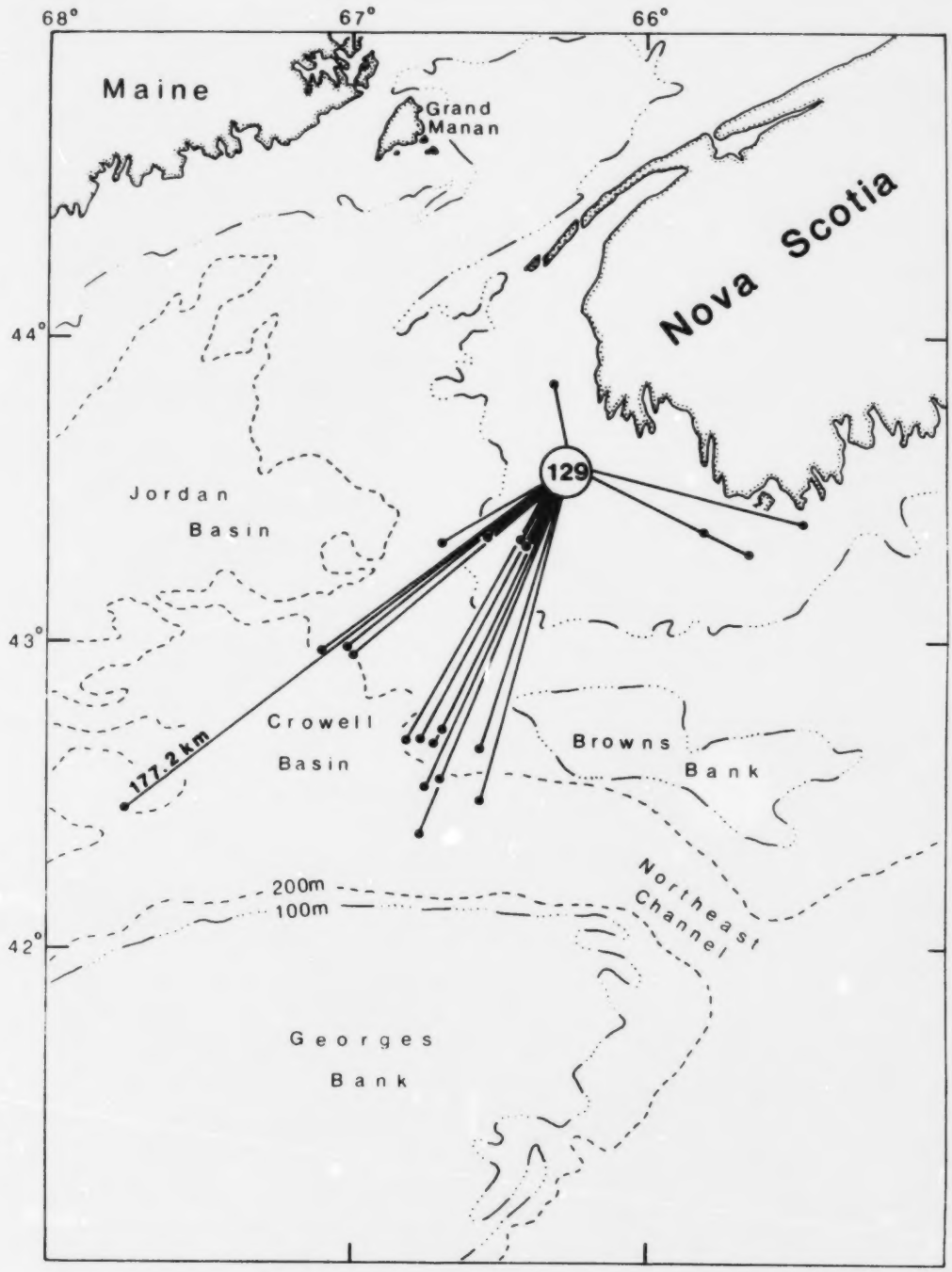

Fig. 6. Recapture points and straight-line distances moved >30 km for tagged lobsters released in area C (the Gulley). Each dot represents one recapture; 129 lobsters were recaptured within 30 km of the release area C.

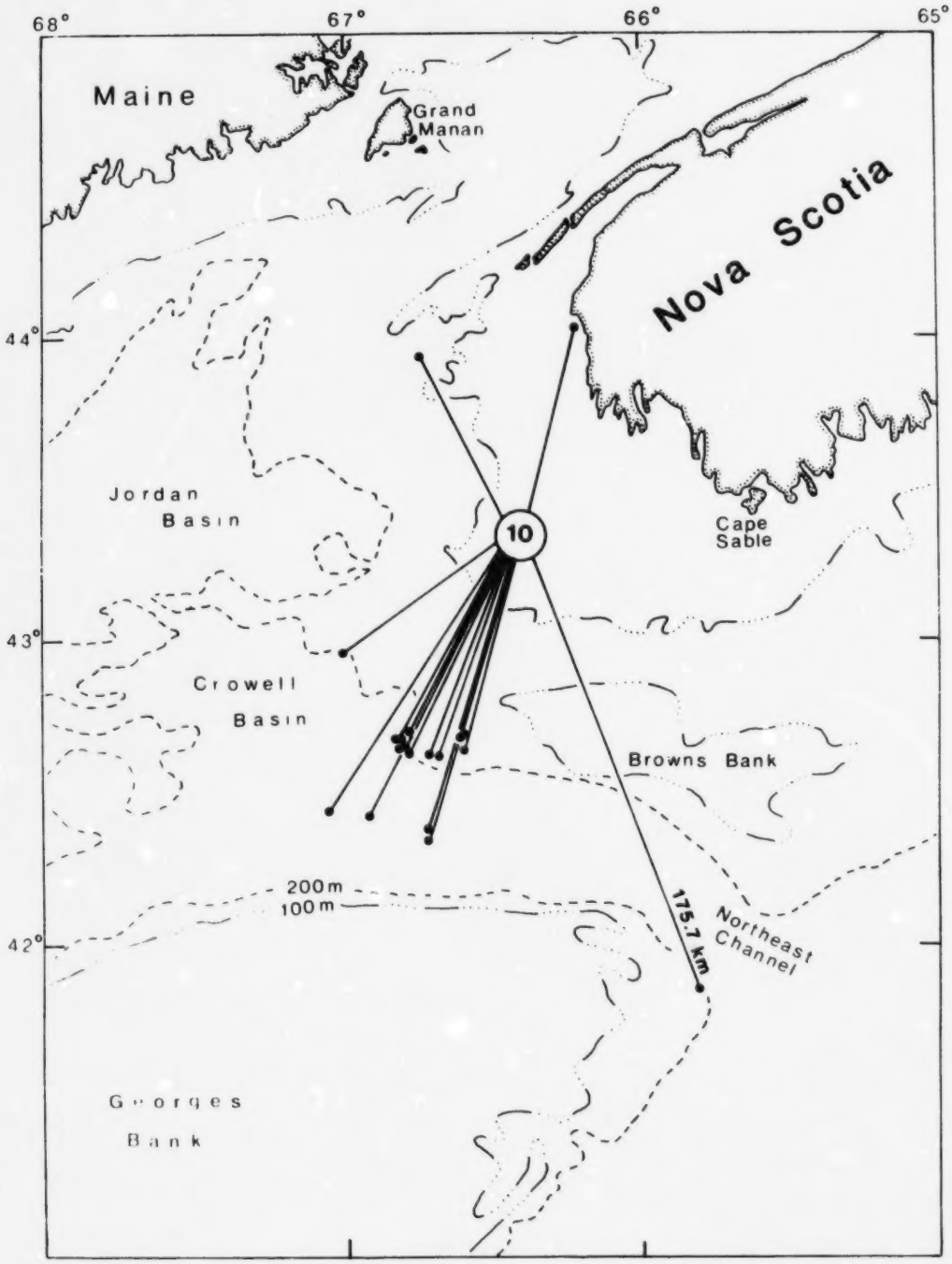

Fig. 7. Recapture points and straight-line distances moved >30 km for tagged lobsters released in area D (German Bank). Each dot represents one recapture; 10 lobsters were recaptured within 30 km of the release area D.

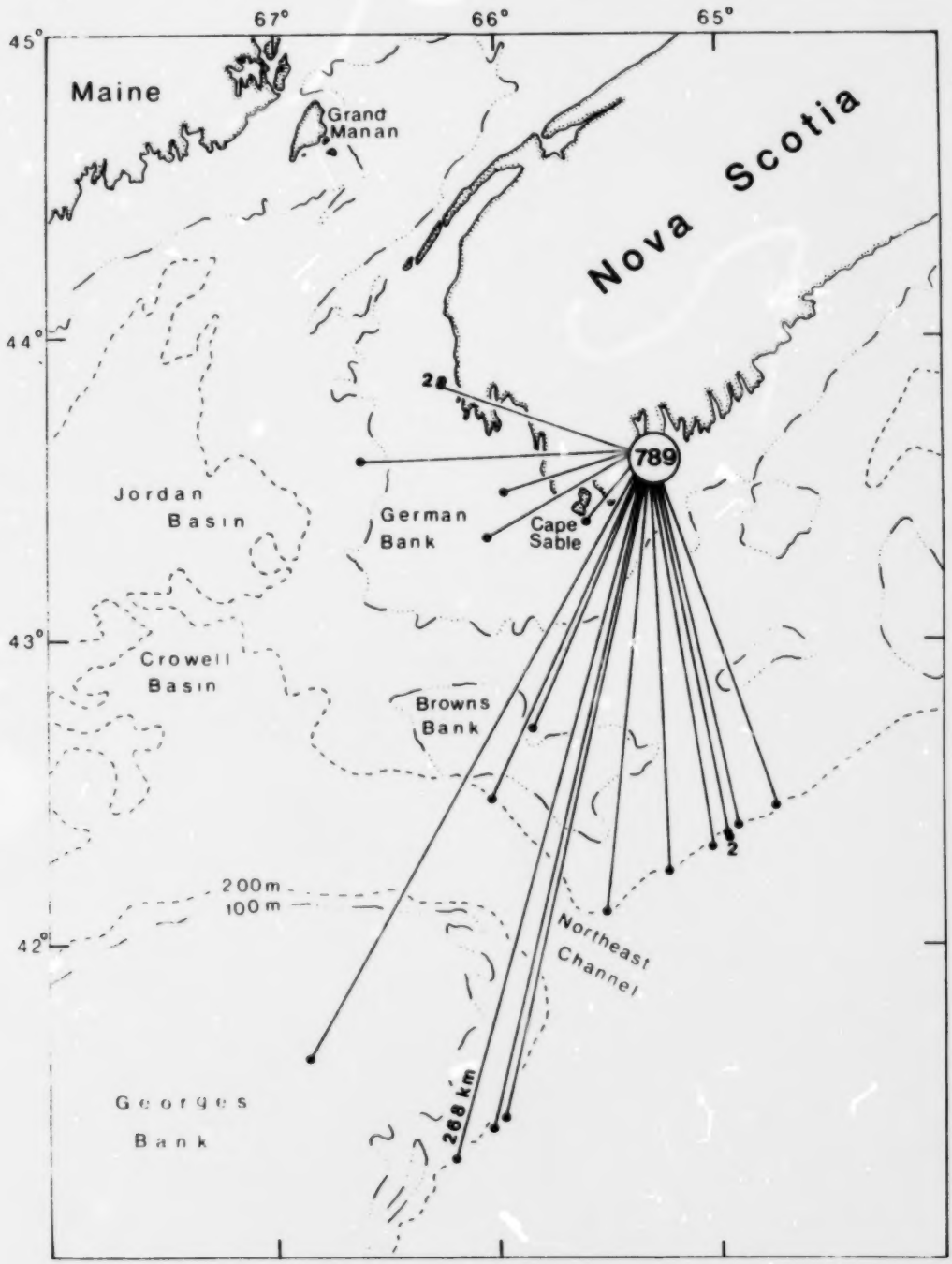

Fig. 8. Recapture points and straight-line distances moved >30 km for tagged lobsters released in area E (near McNutt Island). Each dot represents one recapture, except where a group of dots has a numeral indicating the number of recaptures; 789 lobsters were recaptured within 30 km of the release area E.